

**PRELIMINARY GEOLOGIC MAP  
OF THE SOUTHERN PLOMOSA  
MOUNTAINS,  
LA PAZ COUNTY, ARIZONA**

by

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## Introduction

The southern Plomosa Mountains were the first range in west-central Arizona for which a published geologic map was available [Miller, 1970], and has received more study than most other ranges in the region [Miller, 1966, 1970; Miller and Morton, 1971; Harding, 1978; Robison, 1979; Davis, 1985; Reynolds et al., 1986; Lerch, 1990], but the geology of this area and its relation to adjacent ranges remains confusing. The map area is located in west central Arizona, in the eastern part of the Maria Fold and thrust belt [Reynolds et al., 1986] (Figure 1). In order to elucidate the relationship between Mesozoic and Tertiary structures in

the area, clarify the Mesozoic stratigraphy, and compare the style of mineralization in the southern Plomosa District with that in the Little Harquahala and Harquahala Districts, we have remapped the southern Plomosa Mountains at a scale of 1:24000 [this map] and locally at 1:12000 [Richard, 1991; Richard and Spencer, in prep.]. This report summarizes the lithology of rock units on the 1:24000 scale map, provides a brief discussion of our thinking about the structure and stratigraphy, and a summary of the style of mineralization observed in the area.

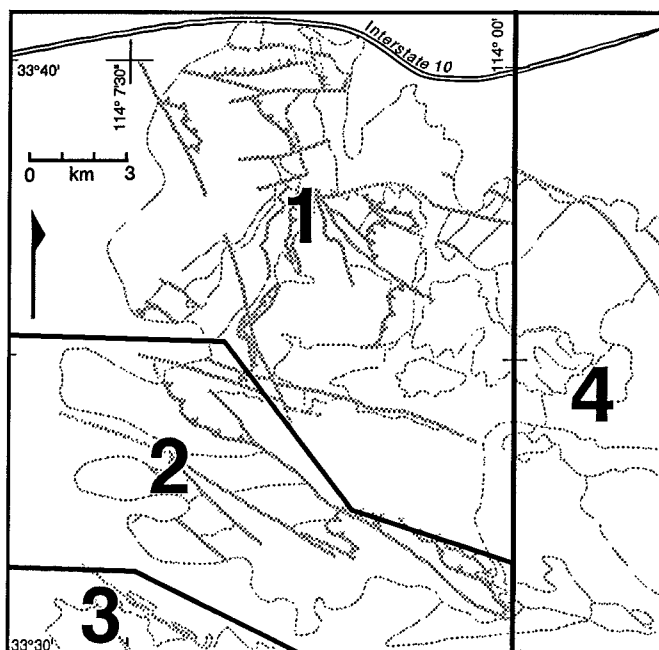


Figure 1b. Map showing sources of geological data for Figure 2 and the map. 1-Richard and Spencer; 2-Richard, Spencer and Stone; 3- Tosdal, Stone and Richard; 4-geology generalized from Vicksburg 15' Quadrangle [Sherrod et al., 1990].

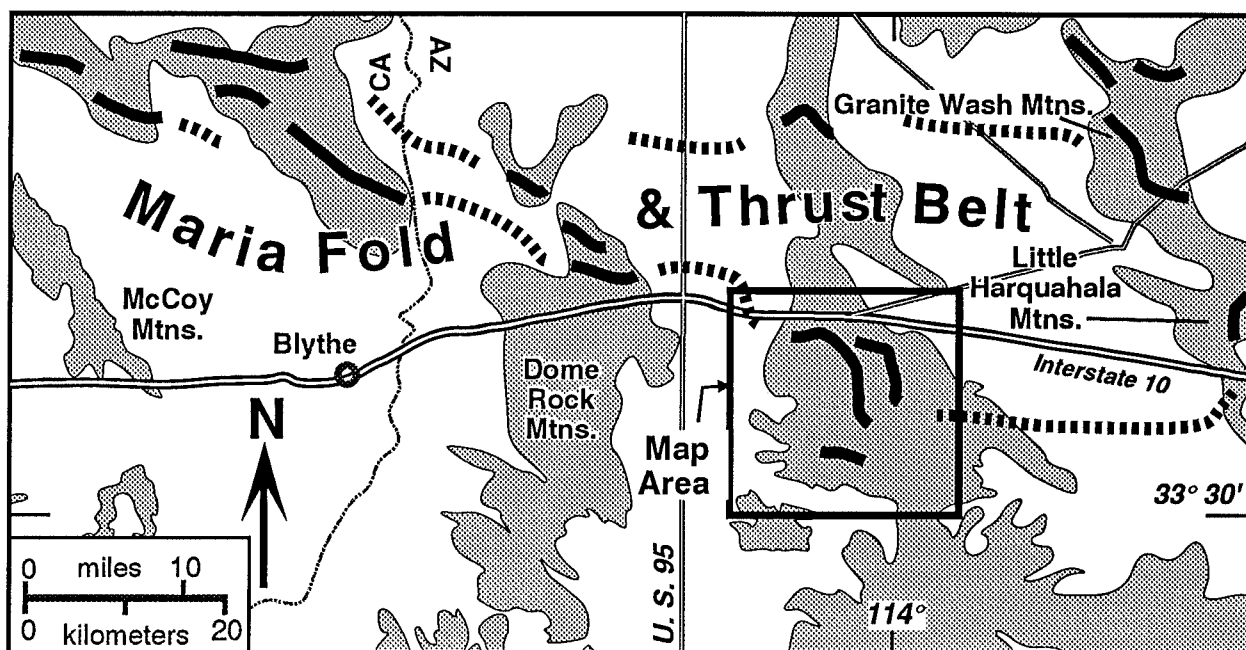


Figure 1a. Map showing location of map area. Major folds and faults of the Maria fold and thrust belt are indicated by the heavy lines.

## Rock Units

### Quaternary

- Qs     **Undivided alluvial sediments**—Undivided alluvial sediments; includes unindurated to poorly indurated sand, silt, and gravel. Generally includes alluvium in active channels, old alluvium underlying adjacent terraces (Qoa), and some colluvium (Qtc).
- Qtc     **Talus and colluvium**—includes talus with little or no matrix and colluvium mantling hill slopes.
- Qoa     **Old alluvium**—generally slightly indurated conglomerate and sandstone. Conglomerates typically are poorly sorted cobble to boulder conglomerate, massive to poorly bedded, with low-angle cross beds and channels preserved. Sandstone occurs as thin, discontinuous lenses.

### Quaternary or Tertiary

- QTc     **Pedogenic carbonate**—massive white, sandy to conglomeratic limestone forming an indurated surficial layer. Base is rarely exposed, but where it can be observed the carbonate is typically 1-3 m thick.
- QTs     **Boulder and cobble conglomerate**—Moderately indurated sandstone and conglomerate, generally buff color; underlies highest geomorphic surfaces preserved. Generally coarser grained and more indurated than Quaternary units.

### Tertiary

- Tss     **Fine-grained sandstone**, with sparse interbedded limestone. Very light grey color, poorly indurated, rarely crops out, but forms characteristic very light colored, spongy soil. Flint present as nodules and discontinuous beds. Possible equivalent of Bouse Formation.
- Tb     **Basalt or basaltic andesite, undivided**—mostly lava flows, but probably includes some intrusive basalt in section below the felsite unit in the eastern part of the map area. Rock is light to dark grey on fresh surfaces, with a very fine-grained groundmass, and 1-5% crystals of olivine (variably altered to iddingsite), pyroxene and plagioclase, typically 1 mm or less in diameter. Where flows are clearly delineated by basal breccia and scoria zones, they are 2-10 m thick. In the eastern part of the map area the crystal content in the flows varies up section from aphyric to ol ± pyx to ol = pyx (with 2 mm pyx crystals) to ol + pyx + plag. The capping flows on Black Mesa contain fresh olivine, pyroxene and acicular plagioclase crystals. The relative freshness of these capping flows is interpreted to reflect the minimal amount of time these rocks have spent below the water table and is not considered a reliable criteria for identification. The top of Black Mesa is blanketed with pedogenic carbonate of unknown thickness.
- Tbu     **Olivine-pyroxene basalt**—upper unit. Basal flow has common 2-3 mm equant pyroxene crystals; variable amounts of brown iddingsite after olivine and pyroxene crystals present.
- Tbl     **Plagioclase-pyroxene basalt**—lower unit; sparse crystals of plagioclase present, ranging in

size from 1mm long acicular crystals to 2 mm blocky phenocrysts. Tiny pyroxene and olivine crystals also present.

- Tbb Basaltic breccia**—red-brown weathering basaltic flow breccia with minor amounts of scoria
- Tbs Basaltic pyroclastic rocks (Miocene)**—red to brown basaltic lapilli to block tuff consisting of scoria, generally poorly indurated and massive. Clasts range from <1 cm to about 1 m in diameter.
- Tbi Intrusive basalt or basaltic andesite**—lithologically identical to unit Tb, but occurs in irregular dikes. Small body that intrudes unit Jqp in the SE part of the map area has a 10-20 cm pyrometamorphic rind of melted and recrystallized Jqp.
- Ta Hornblende-biotite andesite** Dark brown or grey hornblende-biotite-plagioclase andesite(?). Thick lava flows or domes, with 5-10 m of black vitrophyre at the base of the flows, and internal zones of auto brecciation. The dome/flow complex that forms the Dripping Spring survey marker summit consists of at least 3 major flow/domes, with associated carapace breccia (Tab) and pyroclastic rocks (Tts beneath and interbedded with the flows). The flows are lithologically nearly identical. The mesa underlain by Ta just south of the freeway appears to consist of a single flow (the base is not exposed) that has a lower light pink grey devitrified interval (mapped as Ta by Miller, 1970) and an upper grey to dark grey vitric part which forms the top of the mesa (Mapped as QTa by Miller, 1970). These flows have more hornblende than the Tf unit interbedded with basalt north of Black Mesa.
- ..... Internal boundaries between flows or domes
- Tab Andesite breccia**—Massive breccia consisting of angular clasts of Ta in a matrix of comminuted Ta. Clasts are up to several meters in diameter. Contacts with Ta are gradational. The breccia is interpreted as a dome carapace.
- Tr Rhyolite**—Light grey to buff rhyolite and rhyolite breccia. Characterized by 1 mm quartz and biotite phenocrysts.
- Tf Felsite lava**—light pink grey flow banded felsite containing 2-4% 1mm crystals of plagioclase, biotite, and trace amounts of green pyroxene and hornblende. A 2-3 m thick black vitrophyre is present at the base of the unit, overlying 2-15 m of block tuff and tuffaceous sediments (mapped as Tts). A single flow is present in the central eastern part of the map area, approximately 40 m thick; this flow thins rapidly to the N and NW. Probably equivalent to the rhyolite unit of Sherrod and others [1990] (unit Tr) in the adjacent Vicksburg Quadrangle; Sherrod and others [1990] report a biotite K-Ar date of  $19.8 \pm .4$  Ma (biotite) from this unit, and correlate it with the 'older hornblende-biotite andesite' of Miller [1970], which has yielded K-Ar dates of  $19.6 \pm .6$  and  $20.7 \pm .6$  Ma (hornblende and biotite respectively) [Miller and McKee, 1971; recalculated to new decay constants].
- vvvvvvv Vitrophyre marker bed
- Tfi Intrusive felsite**—lithologically identical to felsite lava, but contacts are vertical and cross-cutting, with 10-20 cm of vitrophyre locally present along contact.
- Tt Welded tuff**—brown weathering dacite(?) tuff containing 5-7% 1 mm crystals of hornblende and plagioclase, with sparse biotite, and trace amounts of quartz and pyroxene. At base is a dark brown porcelaneous densely welded zone. Fiamme are black and glassy in densely

welded zone, and light brown (lighter than matrix) in overlying welded tuff; they are generally small (3-5 cm long, ~1 cm thick). Lithic fragments compose about 5% of rock, and consist of dark to light grey and red-brown felsite. Unit probably includes two cooling units, one above and one below the poorly welded tuff unit (Ttu). The lower cooling unit is exposed on the south side of hill 2640, about 1 mi N. of Chalk Tank in the eastern part of the map area; this unit contains sparse blocks of flow-banded felsite (like Tf) and felsite breccia up to about 2 m in diameter, and several internal cooling breaks are present.

**Ttu**    **Poorly welded tuff**—white, non-resistant massive tuff, with crystal assemblage identical to Tt. Poorly welded equivalent of that tuff. Some rocks mapped as Tts are probable equivalent to this unit.

**Tts**    **Tuff and tuffaceous sediments**—buff to white thin to medium bedded massive tuff and laminated reworked tuff. Crystal and lithic content somewhat variable, this unit is a catch all for the thin tuffaceous units present at various places in the section. Irregular and generally anomalously steeply dipping attitudes measured in this unit where it is deposited on pre-Tertiary rocks reflect pre-existing topography. This is particularly well demonstrated where the massive, very gently dipping Ttu unit grades into well bedded Tts with dips of 20°-30° along the buttress unconformity W of Chalk Tank, north of Black Mesa. Higher in the section these tuffaceous units are typically interpreted as pyroclastic aprons related to the intermediate to silicic flow units (Tf, Ta and Tr).

**Ttb**    **Block tuff**—poorly exposed block tuff containing blocks of pre-Tertiary rocks up to about 1 m in diameter. Crops out below basalt on hill west of Black Mesa. Probably more widespread than is shown, but impossible to map separately from the conglomerate unit (Tc) due to poor exposures on slopes of Black Mesa. Bedding commonly visible due to internal cooling breaks and crude bedding defined by clast size variations.

**Tc**    **Conglomerate**—Massive cobble to boulder conglomerate. Clasts include all pre-Tertiary units, but clast composition is variable from place to place. Conglomerates in vicinity of the junction of Apache and Italian Washes is nearly monolithologic, derived from Xsm and Yg in the north, grading south to more heterolithic conglomerates southward. The unit in this area includes some sedimentary breccia (Tsb). Conglomerate on the NW slopes of Black Mesa contains abundant clasts of strongly foliated Jurassic volcanic rocks (quartz porphyry), along with Paleozoic sedimentary rocks. Major clast types are indicated in parenthesis. Includes coarse alluvial deposits and debris flows. Much of this unit along Apache and Italian washes was mapped as bedrock by Miller [1970], but recognized by Davis [1985] to be a Tertiary deposit. South and east of Black Mesa, the conglomerate contains abundant large clasts of the Crystal Hill formation, and in places consists entirely of clasts of this unit. Clasts of both massive and foliated Jurassic volcanic rocks, conglomerate and sandstone (units JKc, JKa and JKs), and sparse boulders of vesicular basalt and orange-tan rhyolite welded tuff are also present.

..... contact between lighter and darker conglomerate visible on air photographs (north of Renegade Mine).

-|-|-| contact between conglomerate with Tertiary volcanic clasts (above, to SW) and conglomerate with only pre-Tertiary clasts (below) (SE corner of map area)

**Tsb**    **Sedimentary breccia**— Monolithologic conglomerate and breccia with abundant mudstone to fine-grained sandstone or conglomeratic sandstone matrix. Matrix or clast supported.

Blocks are up to about 3 m in diameter. Unit is interbedded with and grades into conglomerate (unit Tc). Lithology of clasts is indicated in parenthesis, where bodies of monolithologic breccia are large enough to show. Interpreted to include talus, coarse alluvium and debris flow deposits.

- Tbr Monolithologic breccia**—bodies of rock derived from a single parent rock unit, which consist of relatively coherent blocks up to 10 m in longest dimension enclosed in a matrix of breccia with comminuted rock matrix. Contact with coherent (but typically shattered) rock is mapped where preexisting internal structure in the parent rock (e.g. bedding, cleavage) becomes strongly rotated and disrupted between blocks. Also occurs interbedded with conglomerate (unit Tc). Monolithologic breccia grades into intact rock in the Paleozoic section NW of Black Mesa. The breccias in this area preserve the large-scale stratigraphy of the parent Paleozoic section, implying mixing on a scale of less than about 20 m. This unit is distinguished from the sedimentary breccia (unit Tsb) by the lack of epiclastic matrix. This unit is interpreted rock avalanche deposits.

#### Jurassic or Cretaceous

- JKd Diorite intrusions (Jurassic or Cretaceous)**—fine to very fine-grained equigranular diorite or gabbro, consisting of altered hornblende, plagioclase and sparse possible biotite. Hornblende is typically altered to chlorite and actinolite(?) and plagioclase is commonly sericitized. Two major sills intrude the Crystal Hill formation in the Scadden Mountain block and abundant sills are present in the lower part of the sandstone (JKs) west of upper Apache Wash, and in the conglomerate (JKc) west of Dripping Spring summit; andesitic sills are sparse in the Jurassic volcanic rocks. The upper sill in the Crystal Hill formation of the Scadden Mountain sequence is boudinaged in sheared JKh below the fault superposing Kfg on JKh. Lithologically similar sills (JYd) in the Scadden Mountain pluton (Xsm) and in the coarse grained Proterozoic granitoid below the Paleozoic section of the Six Price sequence may be related to those intruding the Mesozoic strata.

**Mesozoic clastic rocks**— Stratigraphically variable conglomerate, sandstone and mudstone in the southern Plomosa Mountains probably correlates with some part of the McCoy Mountains Formation [Harding and Coney, 1985; Richard and others, 1987; Stone, 1990] but due to uncertainty in the age and correlation of the strata exposed in the various fault bounded domains within the map area, they are labeled based on purely lithologic divisions. All of these rocks are considered Jurassic or Cretaceous because they are deposited above Jurassic volcanic rocks and are deformed by pre-latest Cretaceous deformation events. The stratigraphy and correlation of these rocks is discussed in more detail in a following section.

- Mzs Phyllite**—greenish grey to grey chlorite-muscovite-quartz-feldspar phyllite. Associated with carbonate and quartzite tectonites in shear zone just south of Plomosa Pass. May correlate with Buckskin Formation or some part of the McCoy Mountains formation.
- JKsu undivided sandstone and conglomerate**—may include JKf, JKs, JKc, and JKa. Rocks labeled JKsu were not studied in detail to subdivide them further
- JKsh shale**—light grey silvery phyllitic shale. Contacts with sandstone above and below are gradational. Mapped only in Livingston Mine section.
- JKf Fine-grained clastic rocks**—very thin bedded, locally laminated, mudstone, siltstone and very

fine-grained lithofeldspathic sandstone. Thin cobble conglomerate beds are present. Generally medium to dark grey weathering, with phyllitic sheen; locally greenish grey or brown weathering. Distinguished by very thin bedding and fine grain size. Forms wide outcrop area east of Apache Wash, but variable, typically gentle to moderate dips and the presence of open upright folds suggest that the stratigraphic thickness is much less than the width of outcrop would indicate. Contact with megablock conglomerate east of Apache Wash is abrupt fining upward gradation over about 10 m. Southwest of Dos Picachos volcanic lithic sandstone that overlies the Crystal Hill formation grades up into laminated fine-grained clastic rocks lithologically identical to the rocks east of Apache Wash. The contact is in a zone of strong cleavage, and becomes sheared to the north towards Dos Picachos.

- JKs Sandstone—massive to medium bedded sandstone. Fine to coarse grained lithofeldspathic sandstone and conglomeratic sandstone, generally medium grey to greenish grey. Characterized by monotonous, relatively homogeneous sandstone, in which bedding orientation is commonly difficult to see.
- JKa Arkosic to feldspathic sandstone and conglomeratic sandstone with minor interbedded conglomerate—Typically more quartz-rich and less lithic (in field appearance) than sandstone mapped as JKs. Associated with Crystal Hill formation in gradational contacts into more lithic sandstone above (Livingston Mine section) or below (Crystal Hill section).
- JKq Vitreous quartzite—Fine-grained, massive quartzite beds 2-3 m thick. Exposed on pediment west of Dripping Springs Mountain; due to scattered outcrop the stratigraphic position of this unit is unclear.
- JKvs Volcanic lithic sandstone—generally highly cleaved, porcellaneous and massive with scattered but ubiquitous 1-3 mm round quartz grains.
- JKsc Sandstone and conglomerate—thin to medium bedded interbedded sandstone, conglomeratic sandstone and conglomerate. Siltstone or mudstone partings are common. Sandstone is lithologically similar to that in the sandstone unit (JKs), but this unit is typically well bedded, and is lithologically more variable.
- JKc Conglomerate—Massive cobble to boulder conglomerate. Clasts include Jurassic volcanic rocks (Jv), lower Paleozoic formations, and Proterozoic granitoid (unit Yg). Bedding is absent. Varieties are subdivided locally based on predominant clast types:
- JKcl—Limestone clast conglomerate
- JKca—Arkosic matrix with abundant granitoid clasts
- JKcm—Mixed clast-abundant Paleozoic carbonate clasts (recognizable lithology), Jurassic volcanic clasts, and granitoid clasts
- JKcc—Non-descript carbonate clasts, abundant quartzite
- JKcv—Abundant Jurassic volcanic clasts
- JKbr Breccia—monolithologic breccia consisting of angular clasts of grey vitreous quartzite in a matrix of comminuted quartzite. Unit is well indurated. Associated with Jurassic rhyolitic tuff at the base of the clastic section west of Apache Wash. Mixing of quartzite blocks in tuff near several of these breccia lenses suggests that they may be related to caldera margins formed during eruption of the tuff. Quartzite may be Coconino or a Mesozoic quartz-

ite similar to the Vampire quartzite of the Buckskin Mountains [Reynolds et al., 1987]

**JKmb** Megablock conglomerate and breccia—blocks of Paleozoic and Proterozoic rock up to about 50 m in long dimension enclosed in a matrix of lithofeldspathic to arkosic sandstone and conglomerate. Two types have been observed: 1) Yg/Cb and quartzite cobble conglomerate type present in a zone below the Poorman thrust in the eastern part of the map area. This type consists of 1-50 m long blocks which appear to be internally coherent (locally depositional contacts between Cb and Yg are preserved) thin sheets with a sandstone and conglomeratic sandstone matrix (like JKs). Depositional contacts between sandstone matrix are locally preserved, indicating that the mixing of the blocks in the sandstone is primary. The matrix is an arkosic grit apparently consisting largely of disaggregated Yg. In outcrops east of Apache Wash the blocks become mostly Redwall and Martin Formation westward towards the wash. The unit apparently grades into sandstone (JKs) or sandstone and conglomerate (JKsc) to the east both in the Poorman Mine area and in the southeastern part of the map. The contact with Crystal Hill formation (JKh) in the southeastern part of the map is interpreted to be depositional; an interval of bleached JKc, and local angular clast conglomerated derived from JKh is present along the contact. Whatever its nature, it pre-dates the formation of cleavage in rocks adjacent to the contact.

2) The second megablock conglomerate type is present in a thin interval between the chaos unit (JKch) and conglomerate SW of the Apache Chief mine. This unit contains much less matrix, and consists of large blocks or sheets of Dm, Mr and Cb separated by thin lenses of calcareous lithic sandstone. Thin limestone beds with algal structures are rarely present in these sandstones.

**JKch (Pzl; DMu)** Chaos—complexly mixed lenses and blocks of Cb, Dm, Mr, Jv and rarely Pk?. Contacts are faults, no matrix is present. Blocks are 5 to several hundred meters long. The unit was not mapped in sufficient detail to establish the geometry of the individual blocks, but several masses of Jurassic volcanics (Jv) have been mapped. Association with the megablock conglomerate and the presence of conglomerate apparently in depositional contact on the west side of the unit north of Dripping Springs suggest a sedimentary origin as a large rock avalanche deposit. Complex intermixing of Jurassic volcanic rocks (interpreted to be welded tuff) within the unit suggests the possibility that the unit is related to a caldera collapse event associated with Jv. Alternatively the chaos may have developed as a series of rock avalanche deposits or by mixing in a fault zone. This unit is considered a likely protolith for the complexly mixed carbonate, quartzite and metagneous tectonites in the deformation zone on the south side of Plomosa Pass west of Guadalupe Mountain.

**JKh** **Crystal Hill formation**— interbedded quartzite cobble conglomerate, quartzite, calcareous quartz arenite, and fine to very-fine grained purple sandstone. Thin to thick bedded. Equivalent to continental red bed deposits of Miller [1970]. Informal name proposed here for lithologically distinct quartz-rich sedimentary rocks previously included as the basal units of the McCoy Mountains Formation [Harding and Coney, 1985; Stone, 1990]. In the Plomosa Mountains area these sediments are overlain in angular unconformity by younger Mesozoic conglomerates on the northern side of the Livingston Hills [Tosdal and Stone, in press] and in the Crystal Hill and Apache Wash sections within the map area.

**JKhc** basal conglomerate of the Crystal Hill formation— locally differentiated where thick enough to show. Angular to sub-rounded clasts of Jurassic volcanic rocks and sediments derived from Jurassic volcanic rocks, Proterozoic volcanic rocks (like unit Xh or Xv),



Scadden Mountain quartz monzonite(?), bull quartz and subrounded to rounded vitreous quartzite clasts. Massive; cleavage obscures sedimentary structures. Matrix is lithic sandstone; conglomerate is clast supported.

Jurassic

- Jvs**     **Sediments derived from quartz porphyry**—very light grey to greenish grey volcanic lithic sandstone derived entirely from Jurassic quartz-feldspar phyric ash flow tuff. Bedding commonly visible as faint lamination or fine-grained partings. Contains more crystals and visible lithic fragments than JKvs.
- Jrv**     **Undivided volcanic rocks**—quartz-feldspar phyric welded tuff and hypabyssal intrusions that may correlate with Jxt<sub>1</sub>, Jxt<sub>2</sub>, Jxq or be unrelated to any of these. Generally massive and featureless, but fiamme and lithic fragments are sometimes visible on properly weathered surfaces. Similar volcanic rocks exposed in the Black Rock Hills at the southern end of the Little Harquahala Mountains have been dated at 155-160 Ma [Reynolds et al., 1987].
- Jvc**     **Volcanic-lithic conglomerate**—Massive conglomerate consisting of subangular to rounded cobbles and boulders of various Jurassic volcanic rocks in a matrix of volcanic lithic sandstone similar to Jvs. Grades upsection into lithofeldspathic sandstone (similar to JKs, mapped as JKsu) in outcrops east of the eastern edge of the map area.
- Jxq**     **Quartz porphyry**—light grey green color, massive quartz-feldspar porphyry, characterized by round quartz phenocrysts up to 6 mm in diameter. Fiamme and lithic fragments very rare.
- Jxt<sub>2</sub>**     **Quartz-feldspar porphyry**—Medium grey quartz-feldspar porphyry. 10-20% crystal; fiamme rare. Equant 2-3 mm quartz and feldspar phenocrysts.
- Jda**     **Tuff and hypabyssal rocks**—dacite or latite tuff, tuffaceous sediment, and probable hypabyssal intrusive rock
- Jxt<sub>1</sub>**     **Quartz-feldspar porphyry**—Medium grey quartz-feldspar porphyry; 10-20% crystals; fiamme common. Equant 2-3 mm quartz and feldspar phenocrysts.
- Jvb**     **Black latite**—Black crystal poor aphanite with sparse plagioclase and K-feldspar phenocrysts 1-2 mm in diameter. May be intrusive.
- Jdf**     **Intermediate Volcanic Rocks**—Dacitic lava flows and associated fragmental rocks and lithic sandstone.
- Jqp**     **Monzogranite porphyry**—Massive, very light grey monzogranite intrusion with 5-20% 1-4 cm potassium feldspar phenocrysts, 5-15% 3-7 mm rounded quartz phenocrysts, and 20-40% 1-3 mm blocky plagioclase phenocrysts in a very-fine grained groundmass. Equivalent to quartz monzonite porphyry of Miller [1970], but that unit included at least two other rock types mapped separately here.
- Jl**     **Latite(?) flow**—Massive dark purple gray lava with local fragmental texture. 2-3% crystals of plagioclase are present.
- Jv**     **Vampire Conglomerate**—Massive purple-gray cobble to boulder conglomerate. Consists of angular to sub-round clasts of Proterozoic volcanic rocks, Scadden Mountain quartz monzonite, and brown crystalline carbonate, and rounded vitreous quartzite clasts. Strong cleavage

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obscures sedimentary structures. Matrix is lithic sandstone to grit. Correlated with the Vampire Formation of the Buckskin Mountains -[Reynolds and others, 1987] by Lerch [1990].

ooooo conglomerate marker bed

..... sandstone marker bed

#### Jurassic, Paleozoic or Proterozoic

**JPXu Tectonite derived from mixed rocks**—JXi with lenses of Paleozoic(?) quartzite and carbonate rocks. Mapped in shear zone south of Plomosa Pass and west of Guadalupe Mountain. JKch is likely protolith, but may represent a tectonized intrusive rock with pendants of Paleozoic strata or mixing might be entirely due to deformation within the shear zone.

#### Paleozoic

##### *Permian*

**Pk Kaibab Limestone**—Grey fossiliferous dolomite and dolomitic limestone; sandy at base in gradation into Coconino quartzite. Crinoid columnals 1-2 cm in diameter are common, Productid brachiopods also present. Upper unit is grey cherty limestone. These correlate with units one and two of the southern Little Harquahala Mountains [Richard, 1982; Spencer et al., 1985].

**Pc Coconino Quartzite**—very thinly bedded white vitreous quartzite; high angle eolian cross beds are visible in good outcrops.

**Pc? Quartzite**—like Coconino, but grayer color. Occurs as blocks in Jurassic tuff (Jrv); may be Aztec-Navajo-like quartzite

##### *Pennsylvanian or Permian*

**Ps Supai Formation**—calcareous quartz arenite, interbedded with sandy limestone, vitreous quartzite and purple siltstone; medium to thick bedded.

##### *Devonian through Permian*

**PMDu Undivided Supai, Redwall and Martin formation**—possibly a Tertiary chaos unit; mapped in area around Gold Nugget mine

##### *Devonian or Mississippian*

**DMu Martin and Redwall Formations undivided**

##### *Mississippian*

**Mr Redwall Limestone**—Massive limestone with lenticular stratiform chert nodules. On the west slope of Black Mesa concentric structure within these nodules is preserved. At the top the section a paleo-karst zone is preserved, with carbonate cemented breccias and irregular (cavern-filling?) pods of purple mudstone.

*Devonian*

- Dm     **Martin Formation**—medium bedded dark grey, brown and tan dolomite. Basal part of unit is sandy and dark brown weathering.

*Cambrian*

- Cba     **Bolsa quartzite and Abrigo Formation undivided**

- Ca     **Abrigo Formation**—thin to very thin bedded quartzite and mudstone. Coarsening upward cycles from mudstone to very thin-bedded fine grained feldspathic sandstone are present in the central part of the unit. Best preserved sections north and west of Black Mesa are cut by numerous faults, making reliable thickness estimates difficult, but the unit appears thicker than Abrigo Formation in the Little Harquahala Mountains.

- Cb     **Bolsa Quartzite**—thin to medium bedded feldspathic and arkosic quartzite. Grades from arkosic grit at basal contact with Yg to thin-bedded fine grained feldspathic sandstone at top. Contact with Abrigo Formation is placed at first mudstone bed thicker than 10 cm.

Jurassic or Middle Proterozoic

- JYcg     **Coarse-grained porphyritic monzogranite**—consists of 40-50% plagioclase in 3-5 mm subhedral blocky grains, 20-30% K-feldspar in 1-3 cm blocky, equant phenocrysts, 15-20% quartz in 2-4 mm grains interstitial to the plagioclase, 5-7% biotite in very fine grained recrystallized clots. Strongly resembles Sore Fingers monzogranite of the Little Harquahala Mountains [Spencer et al., 1985]. Contacts with the Proterozoic monzogranite (Yg) are difficult to locate precisely, and this unit may actually be a phase of Yg; strong hematite-sericite alteration makes recognition of the rocks difficult. Generally finer grained than Yg, with a more porphyritic look.

- JYd     **Diorite**—texturally variable diorite, ranges from very fine to medium-fine grained. Dark greenish grey rock consists of altered hornblende and plagioclase. Occurs as sill (now vertical) intruding Yg just below nonconformity with Bolsa Quartzite. Also occurs as dikes intruding the Scadden Mountain pluton (Xsm)

- JYg     **Granite**—medium grained, equigranular granite, consisting of 40-50% pink K-feldspar in 3-6 mm anhedral to subhedral grains, 20-25% 2-3 mm subhedral blocky plagioclase, 25-30% quartz in 1-3 mm anhedral grains, and 2-4% biotite in variably chloritized and recrystallized 1-2 mm flakes. Typically has bleached look with white sericitized or argillized plagioclase. Unaltered boulders of this granite are present in the conglomerate between Italian and Apache Washes north of the Apache Chief Mine.

Jurassic or Early Proterozoic

- JXg     **Poorman granitoid**—medium grained equigranular monzogranite, consisting of 40-50% subhedral to euhedral plagioclase with rare 1 cm euhedral plagioclase phenocrysts, 30-35% K-feldspar in 2-5 mm subhedral to anhedral grains, 15-20% 1-2 mm anhedral quartz, and 3-5% biotite generally recrystallized to very fine grained clots, but rarely preserved as 3 mm flakes. Ubiquitous sericitization and hematite staining, all biotite looks secondary.

- JXr     **Rhyolite dikes**—light grey aphanitic groundmass with sparse 1-2mm quartz phenocrysts;

lithologically identical to much of the Proterozoic volcanic unit (Xv). Intrude Scadden Mountain quartz monzonite (Xsm)

- JXi     **Metamorphic tectonite**—derived from Jurassic volcanic rocks (Jrv), Scadden Mountain quartz monzonite (Xsm), or Proterozoic volcanic rocks (Xv). Fine-grained to very fine-grained green biotite-white mica-quartz-feldspar groundmass with scattered 1-2 mm porphyroblasts of quartz and feldspar. Rock is strongly foliated and typically has at least two cleavages. The older is a differentiated laminated foliation and schistosity and the younger is a crenulation cleavage

#### Middle Proterozoic

- Yg     **Monzogranite**—coarse grained, slightly porphyritic monzogranite. Consists of 30-35% quartz in 1-5 mm anhedral grains, 30-35% plagioclase in 1-4 mm blocky subhedral grains, 15-25% K-feldspar in anhedral 2-8 mm grains and in elongate blocky, zoned phenocrysts 2-3 cm in diameter, and 3-5% biotite in 1-3 mm very fine-grained recrystallized clots. Equivalent to coarse grained quartz monzonite of Miller [1970]. Lithologically identical to Socorro Granite of the Little Harquahala and western Harquahala Mountains.

#### Early Proterozoic

- Xsm     **Scadden Mountain quartz monzonite**—medium grained equigranular monzogranite to granodiorite; consists of 25-35% anhedral quartz, 40-50% subhedral plagioclase, 10-20% subhedral K-feldspar, and 3-5% 1-2 mm recrystallized biotite clots. Rock is typically moderately to highly fractured. Miller [1970] reports a uranium-lead age of 1730-1750 Ma attributed to L. T. Silver.
- Xh     **Hornfels**—dark reddish grey, greenish grey and grey aphanitic hornfels; locally contains 1-2 mm quartz phenocrysts and a laminated, differentiated foliation, strongly resembling the Proterozoic volcanic rocks associated with the Scadden Mountain quartz monzonite (northern outcrop of pCv unit of Miller [1970], Xv on this map). Other rocks included in this unit are aphyric, aphanitic and homogeneous, and include dikes of unknown (pre-Tertiary) age as well as Proterozoic metavolcanic rocks.
- Xv     **Metavolcanic rocks**—very fine-grained light to dark grey hornfels; ranges from massive to compositionally banded on a decimeter to meter scale, with irregular lenticular lithosomes that apparently represent transposed primary lithologic units. No primary depositional structures or textures have been recognized. The most common lithology is a light grey felsic hornfels with sparse 1-2 mm quartz phenocrysts.
- M—     **old mafic dike**—altered very fine grained, equigranular basaltic dikes. May be related to JYd or JKd. Consist of chloritized amphibole(?) and plagioclase.

## Discussion of Mesozoic Stratigraphy

Six contrasting Mesozoic stratigraphic assemblages characterize fault-bounded terranes in the map area (Figure 2,3):

1) The **Six Price sequence** consists of Proterozoic coarse-grained granitoid overlain by Paleozoic and Mesozoic strata. The Mesozoic section consists of a sequence of Jurassic volcanic rocks including at least 3 quartz-phyric ash-flow tuff units and a heterogeneous unit of dacitic lavas and fragmental rocks; a thin volcanic lithic conglomerate unit caps the volcanic section. Overlying elastic rocks consist of interbedded sandstone, conglomeratic sandstone, conglomerate and mudstone; hypabyssal andesite or basalt sills are abundant, and thin tuffaceous sandstones with quartz phenocrysts(?) are present in the lower part of the section. These rocks have been described in more detail by Sherrod and Koch [1987], and crop out only in the easternmost part of the map area east of Black Mesa.

2) The **Apache Wash sequence** consists of a basal mega-breccia and conglomerate unit overlain by sandstone in a fining-upward sequence. Paleozoic blocks in the mega-breccia include a Cambrian Muav-like lithology not present in the Six Price sequence Paleozoic section. Other common recognizable blocks include Bolsa Quartzite, Abrigo Formation and Martin Formation. Blocks of Supai Formation and possible Coconino Quartzite are rare. Several blocks of cherty limestone that strongly resembles unit 2 of the Kaibab Formation in the Little Harquahala Mountains [Richard, 1982; Spencer et al., 1985] or anomalously cherty limestone marble in the Redwall Formation at the White Marble Mine in the western Harquahala Mountains are also present. The absence of other Kaibab-like blocks in the mega breccia and chaos units suggests that these are probably Mississippian. The thickness and clast size in conglomerate associated with the mega-breccia increases to the south suggesting a source in that direction.

3) The **Scadden Mountain sequence** is especially interesting because Mesozoic volcanic rocks and the Crystal Hill formation directly overlie the Proterozoic Scadden Mountain quartz monzonite. A thin basal conglomerate, correlated with Vampire formation of the Buckskin Mountains is present at the base of the section. This is overlain by Jurassic quartz-feldspar phyric ash flow tuff(?), which grades up into volcanic lithic sandstone derived from the tuff. A 20-30° angular unconformity separates the Crystal Hill formation from underlying Jurassic volcanic rocks and associated sediments, such that the Crystal Hill formation onlaps from the sediments to the volcanic rocks, then directly onto the Scadden Mountain quartz monzonite. A basal conglomerate at the base of the Crystal Hill formation in this section is lithologically nearly identical to the Vampire conglomerate, such that the correlation of basal conglomerate where Crystal Hill formation overlies the Scadden Mountain pluton is uncertain. Two thick greenstone sills intrude the Crystal Hill formation in this section. The Crystal Hill formation grades up into porcellaneous volcanic lithic sandstone, in turn overlain gradationally by laminated, fine-grained sandstone with interbedded thin lithofeldspathic sandstone and conglomeratic sandstone beds. This upper fine grained unit is lithologically very similar to the fine grained unit at the top of the Apache Wash sequence. Stratigraphic relationships in these fine grained

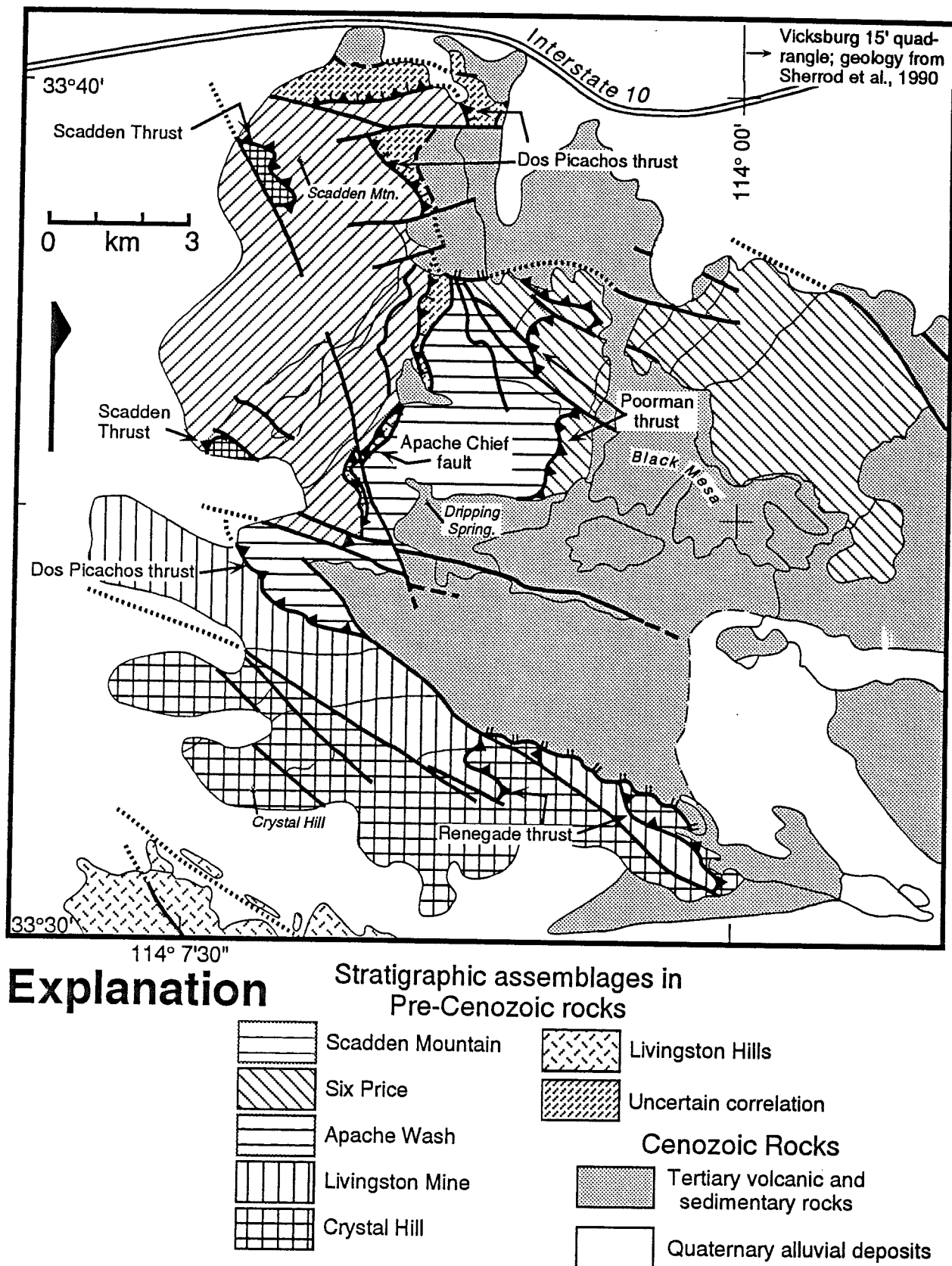
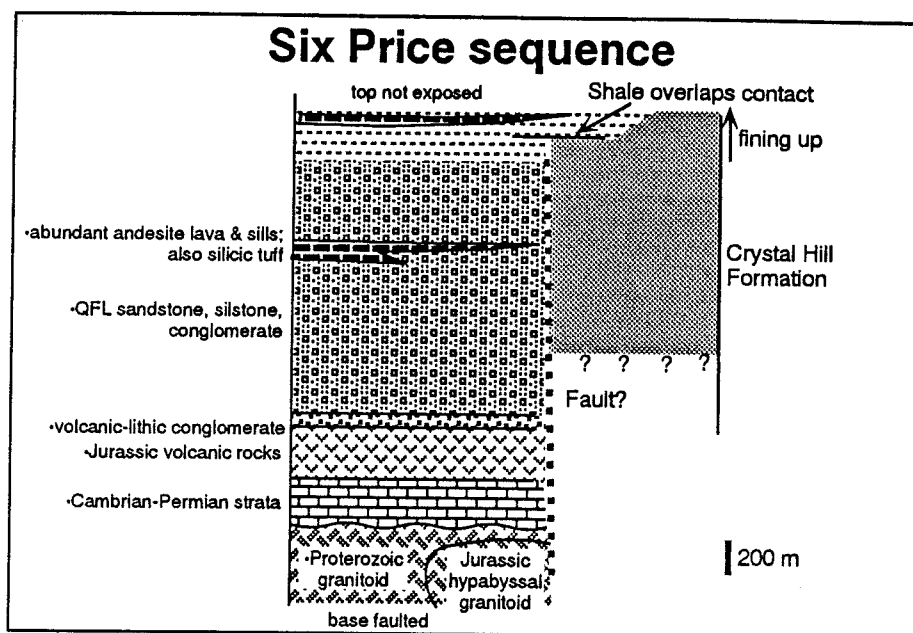
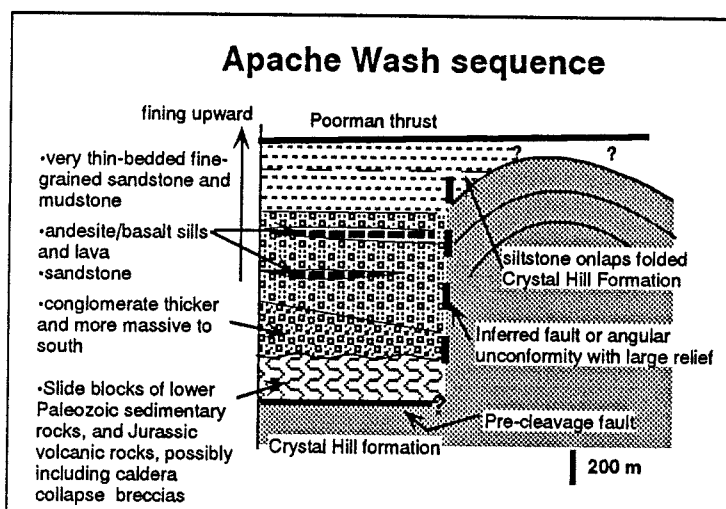


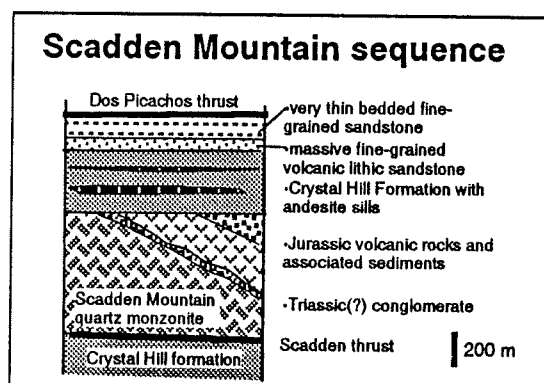
Figure 2. Generalized geology of the southern Plomosa Mountains. Geology of Vicksburg quadrangle from Sherrod et al, 1990. Mapping responsibilities indicated in Figure 1b.



A

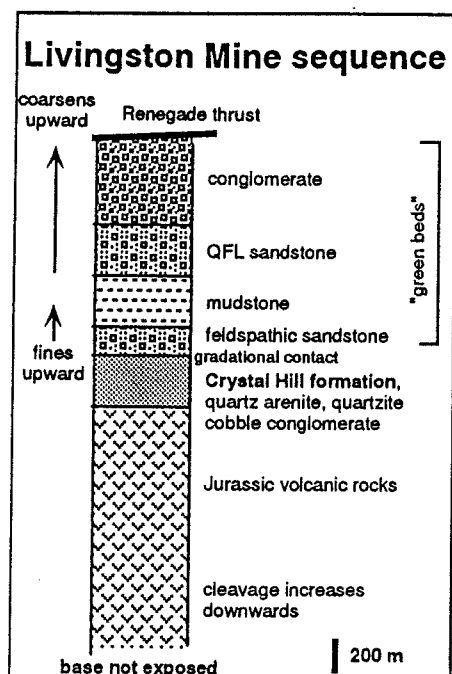


B

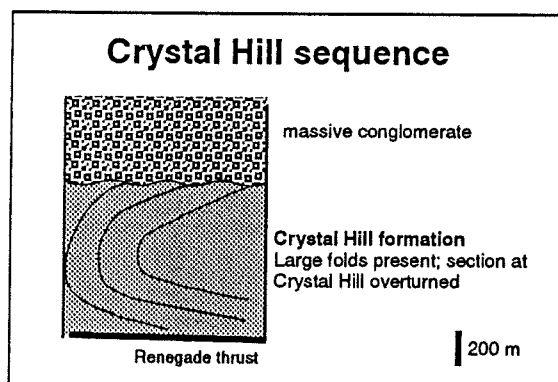


C

Figure 3. Summary of stratigraphic sequences; thicknesses are schematic.

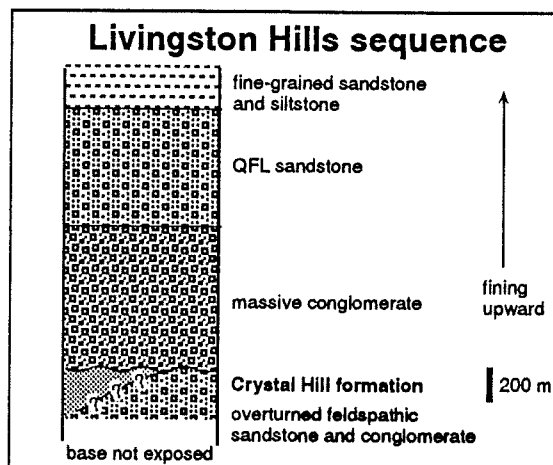
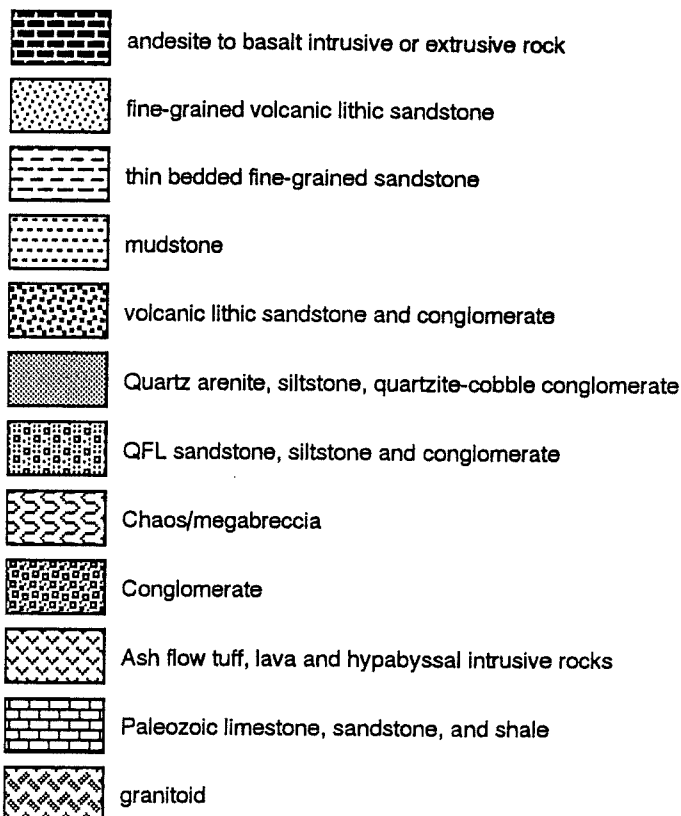


D



E

# Symbols for lithology used on schematic stratigraphic columns



F

Figure 3 continued



units in the upper Scadden Mountain sequence are obscured by strong cleavage developed near the Dos Picachos thrust. The contacts become sheared to the north, and in the vicinity of Dos Picachos, the fine-grained unit is clearly faulted onto the Crystal Hill formation

4) The **Livingston Mine sequence** consists of a thick sequence of Jurassic volcanic rocks overlain by a thin interval of sediments derived from the volcanic rocks. This is overlain by Crystal Hill Formation in the Livingston Mine area. South of the Livingston Mine, the Crystal Hill formation grades up into feldspathic sandstone with a greenish grey color (green beds of Robison [1979]). In the transitional interval, the feldspathic sandstones seem to be interbedded with quartz arenite over an interval of 20-30 m of section. Poor exposure of the section on a pediment also allows the possibility of a fault repetition of the uppermost Crystal Hill formation near the contact. The top of the Crystal Hill formation is placed at the highest quartz arenite bed. Feldspathic sandstone and conglomerate grades up into an interval of silvery grey shale, which coarsen up into feldspathic lithic sandstone and then into conglomerate in the stratigraphically highest part of the

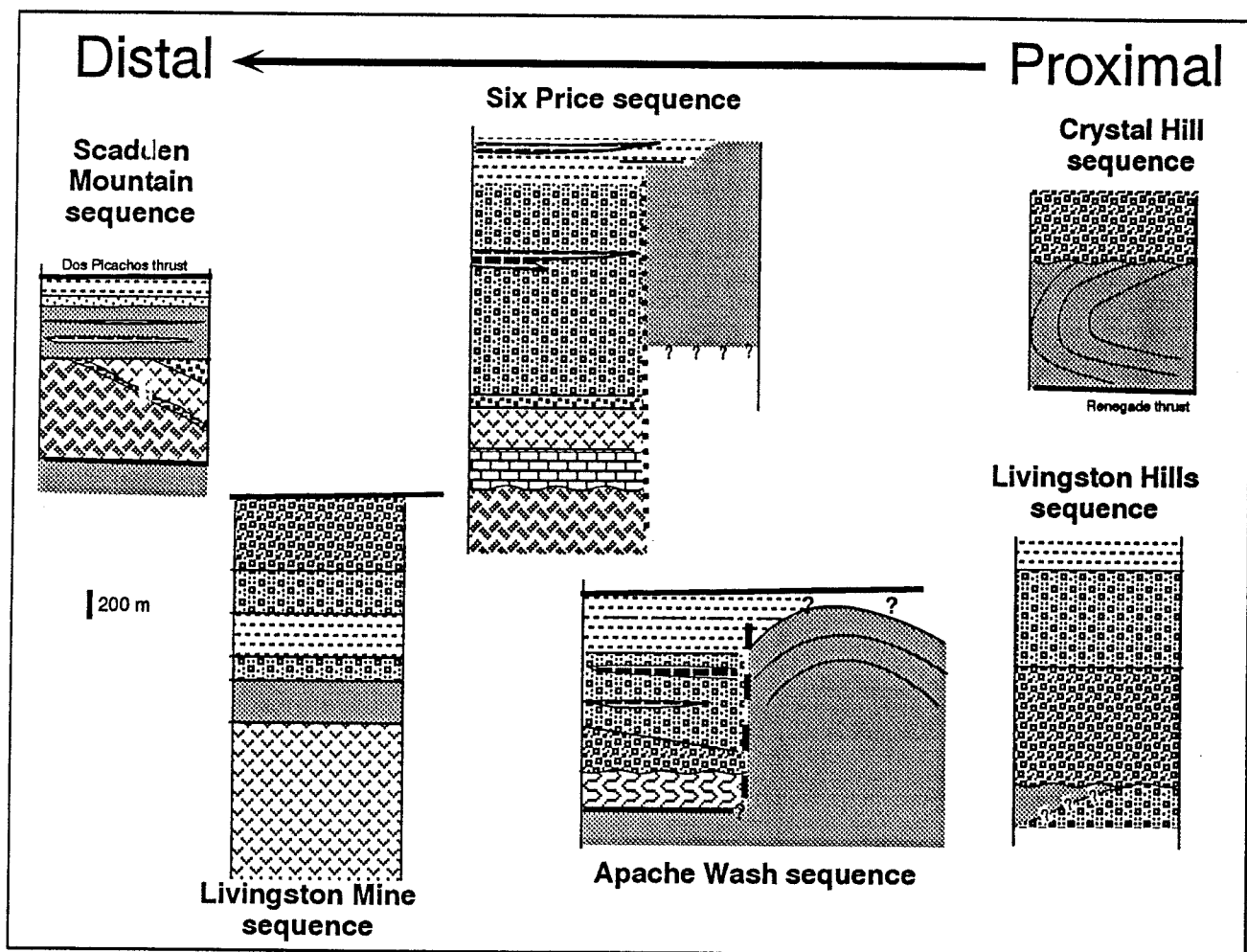


Figure 4. Position of stratigraphic sequences relative to a tectonically active source area.

continuous section. Other feldspathic sandstone exposed north of the pipeline road east of the Renegade mine in the southeastern part of the map area are lithologically like the sandstone in the continuous Livingston Mine section.

5) The stratigraphically lowest unit exposed in the **Crystal Hill sequence** is a porcellaneous volcanic lithic sandstone lithologically very similar to that which overlies the Crystal Hill formation in the Scadden Mountain sequence. This is overlain by conglomerate like that at the base of the Crystal Hill formation in the Scadden Mountain sequence, overlain in turn by a thin interval of feldspathic sandstone like that which overlies the Crystal Hill formation in the Livingston Mine sequence. The feldspathic sandstone grades up into typical Crystal Hill Formation. Tops indicators could not be found in the isolated hills on which this basal sequence is exposed, but bedding on these hills is concordant with bedding on Crystal Hill, where cross beds demonstrate that the section is overturned. East of Crystal Hill is a complexly folded and faulted zone, east of which the Crystal Hill formation is upright and south dipping. In the eastern part of the Crystal Hill domain, Crystal Hill formation grades up into feldspathic sandstone in a sequence like that in the Livingston Mine sequence. In the area of complex folding NE of Crystal Hill, overturned Crystal Hill formation grades up into massive conglomerate. The gradational zone of quartzite cobble conglomerate and feldspathic quartz arenite below the conglomerate is interpreted to represent an interval of recycled Crystal Hill formation, implying that the folding took place before the Crystal Hill sediments were silica cemented. The geometry of this unconformity is similar to that described at the Amuy mine in the northern Livingston Hills by Tosdal and Stone [in press].

6) The **Livingston Hills sequence** is characterized by an upward-fining sequence of conglomerate-sandstone-siltstone [Miller, 1970; Harding, 1978]. At the base of the section in the northern Livingston Hills, the conglomerate overlies feldspathic arenite and conglomeratic arenite along a cryptic contact. Tops indicators in the underlying sandstone suggest that parts of this section are upright and parts are overturned (upright and overturned rocks are on strike with each other, precluding a simple fold interpretation). This sandstone is lithologically most like sandstone that overlies the Crystal Hill formation in the Livingston Mine and Crystal Hill sequences. At the contact, bedding in the sandstone rolls over to parallel that in the conglomerate, and the sandstone and conglomeratic sandstone coarsens into massive conglomerate with no abrupt lithologic break. East along this contact (just south of the map area), the Livingston Hills conglomerate overlies Crystal Hill formation in a pronounced angular unconformity similar to that in the Crystal Hill sequence [Tosdal and Stone, in press]. We interpret that conglomerate of the Livingston Hills sequence overlies a section like the Livingston Mine sequence in profound angular unconformity along the northern edge of the Livingston Hills, such that the feldspathic sandstone below the conglomerate in the map area is stratigraphically associated (probably overlying) the Crystal Hill formation exposed below the conglomerate at Amuy Mine.

These sequences can be organized into a continuum of depositional settings proximal to a high-relief source area to distal from the source area (Figure 4). The kinematics of structures bounding these stratigraphic domains are too poorly constrained to allow reconstruction of their pre-faulting configuration, and the sedimentological characteristics of the stratigraphic sequences likewise do not dictate their original configuration.

We have chosen to use lithologic map units as much as possible on this map because of the problems still outstanding in the regional correlation of Mesozoic units in west-central Arizona and adjacent California. Existing data [Stone et al, 1987; Tosdal and Stone, in press] strongly suggest that the upper conglomerate-sandstone-siltstone sequence in the McCoy Mountains Formation of the Dome Rock and McCoy Mountains is upper Cretaceous in age. Most likely, the conglomerate in the Livingston Hills correlates with these units, given the lithologic similarity and its position above an unconformity separating it from rocks typical of the lower part of the type McCoy Mountains formation (Crystal Hill formation of this report). The relationship of the conglomerate-sandstone±siltstone sequences of the Apache Wash, Livingston mine and Six Price sequences remains enigmatic. Lithologically and structurally, these rocks are most similar to sections in the Granite Wash and Little Harquahala Mountains, and share with them the presence of locally thick basaltic to andesitic sills, and rarely lavas. The presence of these mafic igneous rocks seems inconsistent with deposition in a late Cretaceous thrust belt as has been proposed for the upper part of the type McCoy Mountains formation [others, Tosdal and Stone, in press]. Such rocks have been reported in the Glance conglomerate of the Bisbee Group in southeast Arizona [Lawton and McMillan, 1993; Dickinson et al., 1989], and seem more consistent with deposition in an extensional basin. Regional relationships dictate that such a basin is more likely early Cretaceous in age [c.f. Dickinson, 1981]. Structural relationships in the map area do not define the relative age of the Livingston Hill conglomerate and Apache Wash-type conglomerates.

Two viable stratigraphic hypotheses are workable. The Apache Wash type conglomerates may be correlative with the Livingston Hill-upper McCoy Mountains Formation type conglomerate. These rocks would have been deposited in a complex of basins within or at the frontal zone of the Maria fold and thrust belt in Late Cretaceous time. Alternatively, the Apache Wash type sediments may have been deposited during an early Cretaceous extensional event related to the formation of the Bisbee trough [Hamilton, 1987; Dickinson et al., 1989], in which case they are entirely older than and unrelated to the upper McCoy conglomerate.

In either of these cases, the regionally distinctive quartz-arenite clastic unit at the base of the type McCoy Mountains formation (basal unit 1 of Harding and Coney, 1985; red beds of Miller, 1970; Crystal Hill formation of this report) is separated from the overlying conglomerate units in the southern Plomosa Mountains by a major angular unconformity. The stratigraphy of rocks preserved above the quartz arenite and below the unconformity is quite variable, and presents the greatest difficulty in stratigraphic correlation. Difficulties with these rocks aside, it does not make sense to include the quartz arenite unit in the same

formation with the conglomerate-sandstone-siltstone sequences above the unconformity in this area, even though a lithologically similar sequence in the McCoy Mountains appears conformable. Thus, we have proposed 'Crystal Hill formation' as an informal new name for the sequence of quartz arenite, maroon to violet very-fine grained sandstone and quartzite cobble conglomerate unit in the eastern part of the Maria belt.

The Crystal Hill formation is named for the section exposed on Crystal Hill in the southern Plomosa Mountains. Although these rocks are overturned, based on cross-bedding in the sandstones, this section represents the thickest, least disrupted section in the area. The continuous section is approximately 450 m thick. If the concordant strata exposed on the hill in SW sec 4, T2N R18W are part of the same section, the total thickness is approximately 830 m. The Crystal Hill formation is deposited on Jurassic volcanic rocks or associated sediments, or on Proterozoic granitoid. It is overlain by Mesozoic clastic rocks, but the stratigraphy of overlying units varies from fault block to fault block.

### Structure

The stratigraphic domains within the map area are bounded by high and low-angle faults, many of which appear to have polyphase histories. Fault names used here are those proposed in Reynolds et al. [1986]. The Poorman thrust, previously thought to be major boundary, is a minor imbrication of the Six Price and Apache Wash blocks. A minimum of 4 km of SSW transport of the hanging wall is necessary to produce the observed separation of the cut off of steeply SE-dipping Paleozoic strata at the northwest-trending pre-Poorman high-angle fault (Figure 5). This reconstruction demonstrates that a pre-Poorman, northwest-trending high-angle fault (now largely overprinted by minor Tertiary normal slip) is the major structure that juxtaposes the Six Price and Apache Wash blocks. This fault is truncated at the inferred northern continuation of the Dos Picachos thrust along the east side of Scadden Mountain. The Dos Picachos thrust is considered the major fault between the Apache Wash and Scadden Mountain blocks because of the much greater development of tectonite fabric along this contact than along the Apache Chief thrust of Reynolds et al. [1986]. The nature of the Apache Chief thrust, which places the Paleozoic-block chaos/megabreccia unit on top of Crystal Hill formation, is cryptic. It may be a significant pre-Dos Picachos fault or a disrupted depositional contact. We suggest that this contact be referred to as the Apache Chief fault rather than thrust because of this uncertainty.

The actual mineralized low-angle fault at the Apache Chief mine (referred to here as the Apache Chief Mine fault) can be tracked SSE along Apache Wash. It is characterized by a thin zone of bleached rocks with a weak to moderately developed disjunct cleavage. Minor copper mineralization is found at several places along this fault. Miller [1970] shows this fault to bound a block of Crystal Hill formation on its west and south side until the fault intersects the Poorman thrust near the northwest tip of Black Mesa. We have found that the fine-grained upper part of the Apache Wash sequence is deposited on Crystal Hill formation along the southern side of this block (unsurveyed, W of sec. 13, T3 N R18W), and that the Apache Chief Mine fault

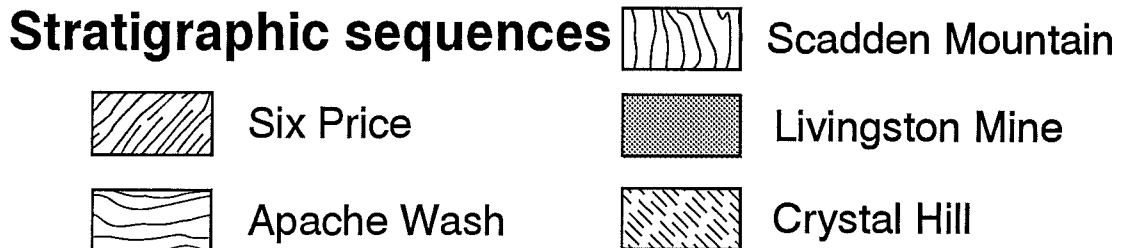
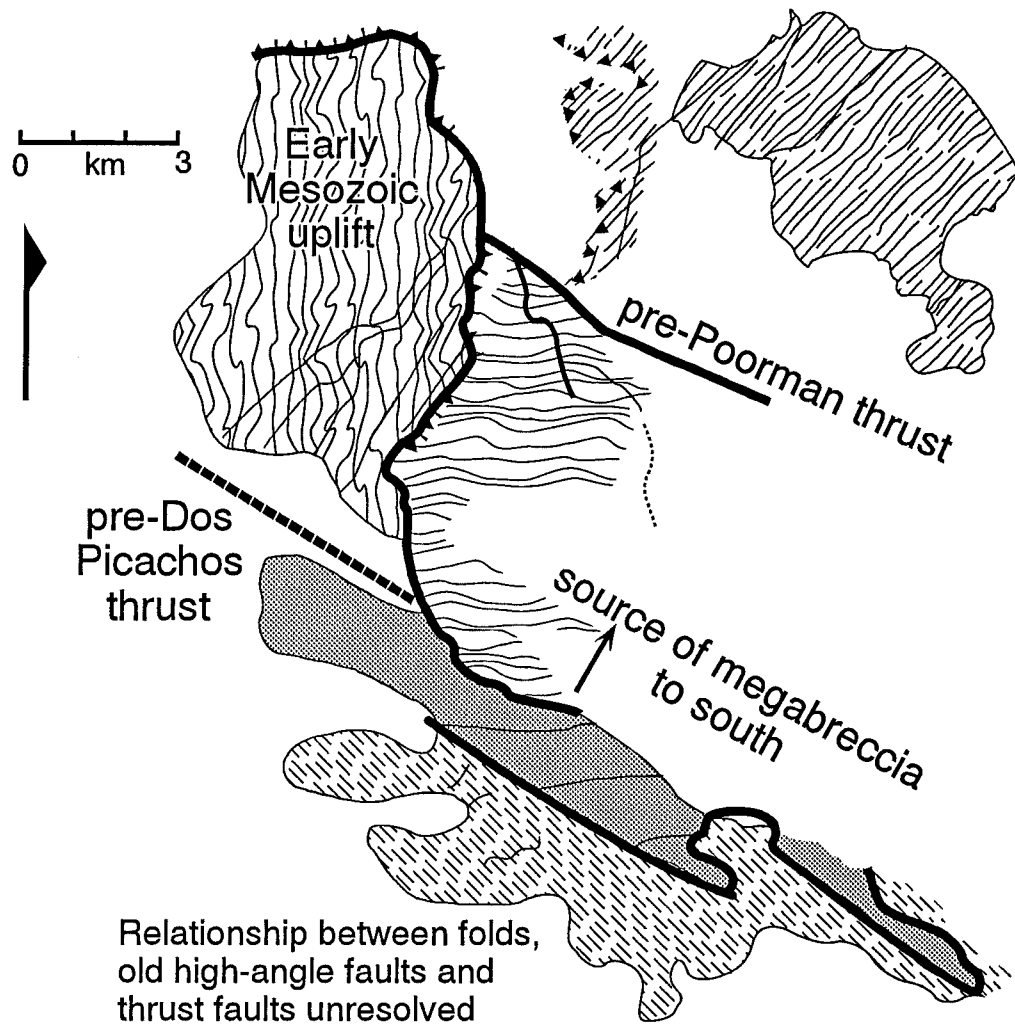


Figure 5. Partial reconstruction of faults in the southern Plomosa Mountains. The hanging wall of the Poorman thrust has been reconstructed 4 km to the NNE to align steeply dipping Paleozoic strata. About 2 km of WNW right separation have been reconstructed on the Tertiary fault south of Dripping Spring summit to align the trace of the Dos Picachos thrust. Right separations on three east to northeast-trending Tertiary high-angle faults along Apache Wash have been reconstructed to align the trace of the Dos Picachos thrust.

is either overlapped by the fine-grained sandstone, or it loses definition and dies out in the fine-grained sandstone in the basin area west of Black Mesa. Relations along this contact are also disrupted by an at least partly younger, northwest-trending high angle fault. This depositional contact of rocks of the upper Apache Wash sequence on Crystal Hill formation supports the possibility that the Apache Chief thrust of Reynolds et al. [1986] might be a depositional contact.

The sliver of Crystal Hill formation between the Dos Picachos thrust and Apache Chief fault pinches out north of the intersection of the pre-Poorman northwest-trending fault with the Dos Picachos thrust. This too suggests that the contact between the Apache Wash sequence and Crystal Hill formation (Apache Chief fault west of Apache Wash) is one of the oldest contacts in the map area, and might be depositional.

The southern part of the Dos Picachos thrust overlaps an inferred fault contact between the Scadden Mountain and Livingston Mine blocks. This pre-Dos Picachos fault is constrained by the distribution of outcrops in the basin area west of Dripping Spring to have a northwest trend similar to that of the pre-Poorman high-angle fault. This older fault is not exposed but inferred from the stratigraphic contrast between the Scadden Mountain sequence and Livingston Mine sequence, and the jump from a relatively high stratigraphic position in lithic-feldspathic sandstone overlying the Crystal Hill formation north of the discontinuity to the base of a very thick sequence of Jurassic volcanic rocks on the south side. Although the southern end of the exposed Dos Picachos thrust is most probably now a Tertiary normal fault, the distribution of rocks in the hanging wall requires that the original Dos Picachos thrust overlapped the older northwest-trending discontinuity.

Crystal Hill formation in the Renegade mine area, in the southeastern part of the map area, are superposed on rocks of the Livingston mine sequence along a low-angle fault referred to here as the Renegade fault. Rocks of the Crystal Hill formation in the Renegade mine area are correlated with Crystal Hill formation in the Crystal Hill block across a northwest-trending fault zone of probable Mesozoic and Tertiary age. This interpretation implies that the Crystal Hill block structurally overlies the Livingston Mine block. The Renegade fault might thus correlate with the Dos Picachos thrust, the Poorman thrust, or it might be a structurally higher fault.

Within the Crystal Hill block, a complex zone of folding and faulting separates the eastern part of the block, characterized by a simple, south to SSW-dipping upright homocline from the western part, which is a NNW-dipping overturned homocline. This deformation zone starts about 1 km east of Crystal Hill. NW to W-dipping cleavage in the deformation zone is apparently axial planar to a pinched syncline cored by conglomerate (W of center, sec 11, T2N R18W). The conglomerate overlies overturned Crystal Hill formation depositionally, and the cleavage formation thus post dates the overturning of section at Crystal Hill. Slivers of Proterozoic(?) granitoid (Yg?) in the conglomerate in the core of the syncline may be slide blocks in the conglomerate, the granitoid may be a Jurassic or Cretaceous intrusive rock, or there may be a significant fault along the hinge of the syncline. Field relations seem most consistent with the slide block interpretation.

In summary, two major lithologic discontinuities in the southern Plomosa Mountains are northwest-trending high(?) -angle faults that pre-date thrust faults in the area. Miller and Morton's [1970] interpretation that major northwest-trending strike slip faults are present remains valid, but the faults are pre-Tertiary. Megabreccia in the Apache Wash sequence was deposited from a source to the south, presently not exposed

or removed by subsequent fault slip or erosion. This source may be related to the old northwest-trending faults, or record an even older deformation event. Dramatic changes in the thickness of Jurassic ash-flow tuff units suggests that Jurassic caldera collapse structures may be present in the area. Quartzite breccias (Pc?) in Jurassic tuff blocks in the Apache Wash breccia may record caldera collapse. The Dos Picachos thrust is the major low-angle discontinuity in the map area; data available are insufficient to determine its direction of transport. The Apache Chief fault of Reynolds et al. [1986] may represent a disrupted depositional contact. The Poorman thrust is probably a relatively minor fault; it has a minimum of 4 km top-to-the-SSW slip. Early Miocene northeast to east trending faults along lower Apache Wash, and northwest-trending faults in the central and southern part of the map area disrupt the older structures, and are apparently mostly normal faults, but actual slips are poorly constrained. The Black Mesa basalts (unit Tb) overlap these faults.

### Alteration and Mineralization

The total district production for the southern Plomosa mining district of Keith et al. [1983a] is 457000 lbs of copper, 5000 lbs of lead, 1000 oz of gold and 26000 oz of silver [Keith et al., 1983b]. This production has been from high grade veins and from placers. Veins in the map area are observed primarily in two settings (Figure 6): 1) quartz veins cutting all pre-Tertiary rock units and 2) along mineralized faults. Numerous quartz  $\pm$  calcite veins are found throughout the map area; Figure 7 summarizes the orientation of measured veins. Where the veins are mineralized, they typically contain specular hematite, red iron oxides replacing pyrite or less commonly chalcopyrite, and sparse malachite and chrysocolla. Sphalerite(?) is rarely present. Galena is locally abundant in veins cutting the Scadden Mountain quartz monzonite. Sericitic, bleached selvages occur along the margins of the quartz veins. In the Crystal Hill formation in the Livingston Mine area, the quartz veins are associated with irregular zones of tourmaline replacement and minor copper mineralization (totally oxidized in surface exposures). Transparent quartz crystals grown in open space in these veins, mostly where they cut quartzite beds in the Crystal Hill formation, are the namesake of Crystal Hill and of the town of Quartzsite, Arizona. Veins with abundant quartz crystals are generally barren of base or precious metals. Quartz and quartz-calcite veins in Crystal Hill formation typically cut thick quartzite beds and pinch out in adjacent maroon or purple-grey fine-grained sandstone beds. In the Livingston Mine area, and in the shear zone placing Scadden Mountain quartz monzonite on Crystal Hill formation in the northwestern part of the map area, the veins are buckled in the cleavage in the fine-grained sandstone, indicating that some cleavage development post-dates some of the veins. Quartz in most of the veins is shattered due to post vein brittle deformation; crushed quartz is recemented with quartz or calcite.

The biggest producers in the district are located along post-cleavage low-angle faults. Mineralized faults are characterized by gouge zones with sericitic alteration in and adjacent to the fault. Earthy hematite and sparse malachite and chrysocolla are present along these fault zones. Tertiary volcanic rocks throughout

the map area are typically fresh; the mineralization is thus pre-volcanic. In particular, the absence of veins or other mineralization in the andesite around Dripping Spring indicates that mineralization predates the crystallization of this andesite at ~22 Ma [Miller and McKee, 1971].

Granitoids in several parts of the range are overprinted by extensive, low-grade alteration in which plagioclase is sericitized, biotite replaced by secondary biotite or chlorite, epidote and hematite staining is developed along fractures. The coarse-grained Proterozoic granitoid along the contact with Bolsa quartzite in the area north of Black Mesa is one such rock. It is found in a structural setting and has an alteration style

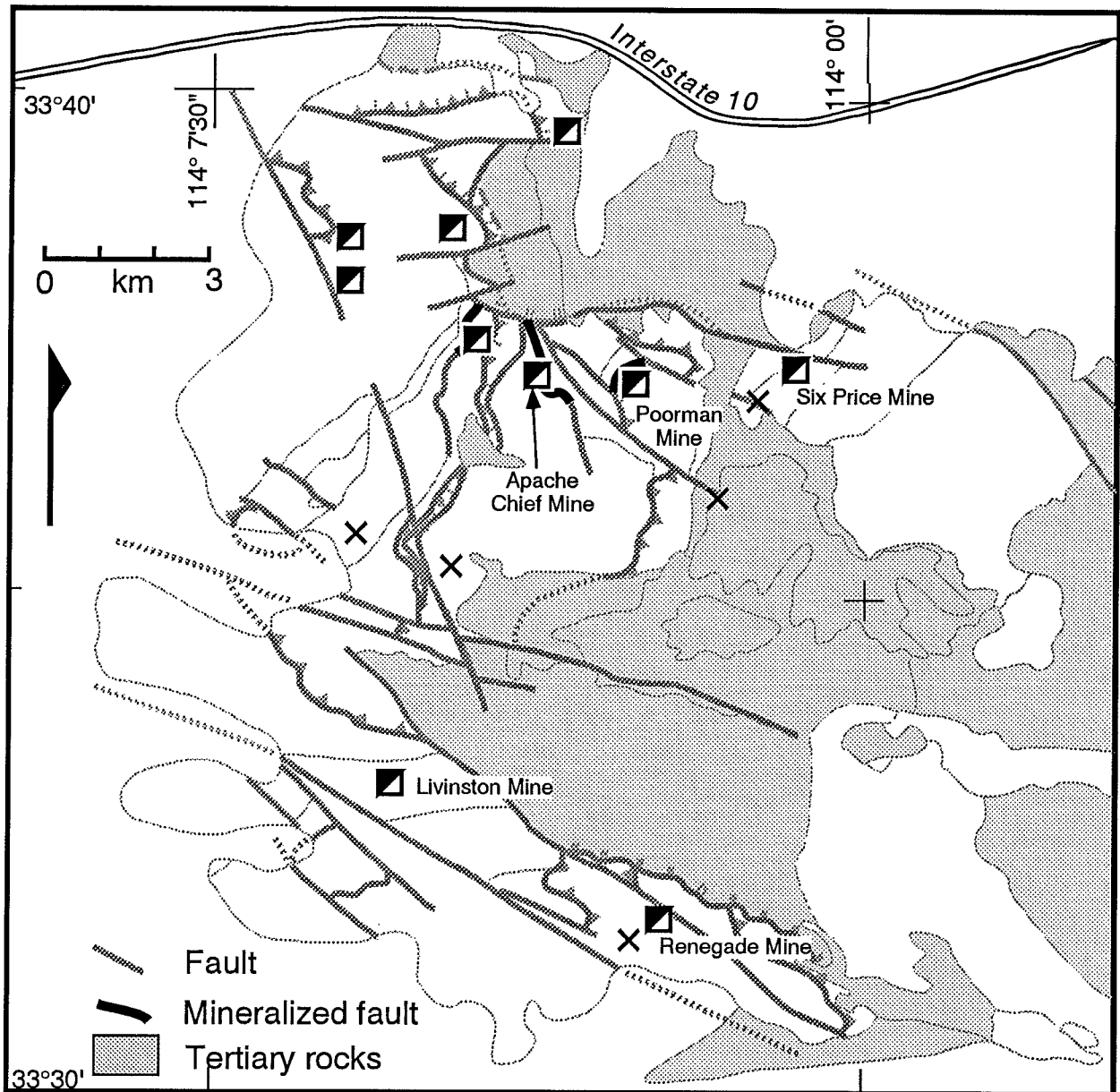


Figure 6. Location of mines and prospects in the southern Plomosa Mountains.



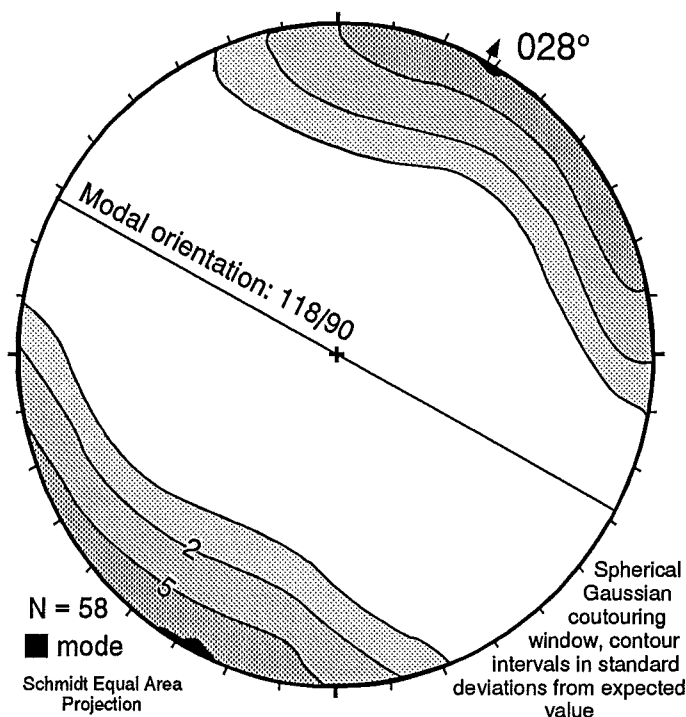


Figure 7. Contoured stereonet plot of poles to quartz veins in the southern Plomosa Mountains.

very similar to that of the Bonanza, Golden Eagle and Socorro Reef mines of the western Harquahala Mountains area. Rocks adjacent to the Jurassic monzogranite porphyry west of Black Mesa are pervasively weakly to strongly sericitized and hematite stained, particularly the Poorman granite above the Poorman thrust in the Poorman Mine area. The Scadden Mountain quartz monzonite along the NNW-trending fault through the Plomosa townsite on the north-western side of the map area is extensively altered, and northwest-trending quartz veins are associated with the alteration zones. It is probable that these more extensive alteration zones are related to the same hydrothermal event that formed the quartz veins.

Prospectors at the Renegade mine reported that gold at this mine occurred in 1-3 cm diameter, oxidized pyrite cubes scattered in fine-grained beds in the Crystal Hill formation. Similar oxidized pyrite cubes are present in the Crystal Hill formation at its contact with the fine-grained sandstone unit (JKf) east of Apache Wash.

West of Black Mesa on the flanks of hill 2927, the contact between monzogranite porphyry (Jqp) and monzogranite (Yg) is occupied by two veins up to 4 m thick, one on each side of the hill. The veins consist of massive specular hematite, red and brown hydrothermal carbonate, and sparse quartz crystals up to 2 cm long. The mine shaft and prospects north of hill 2927 are along the mineralized contact. Association of iron oxide (generally magnetite) skarn deposits with Jurassic granitoids in the Mojave desert region [e. g. Hall and others, 1988; Spencer, 1990] supports the interpretation that the monzogranite porphyry is Jurassic in age and that the veins are related to porphyry intrusion.

One striking feature of the mineralization in the area is the lack of any igneous system that can be directly associated with the ore deposits, except possibly some of the alteration around the Jurassic porphyry west of Black Mesa. Based on reconstruction of Tertiary extensional structures in the region, and the very low metamorphic grade of rocks in the southern Plomosa Mountains, these rocks are interpreted to represent a high structural level in the Mesozoic crust. Pre-Miocene hydrothermal activity may have been driven by dewatering of metamorphic rocks in the footwall of thrust faults of the Maria Fold and thrust belt [Spencer and Reynolds AIME paper].

Placer gold has been produced from old alluvium in the Plomosa townsite area. Local prospectors report that the gold is associated with galena nuggets. A number of drainages in the outcrop area of the Tc conglomerate unit in the southern part of the map area have been worked by dry washing and probably yielded some gold as well. Local prospectors report that gold nuggets have been found in surficial deposits near the northwest-trending fault that bounds the conglomerate on the southwest.

### Acknowledgements

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